Concept Paper

Baseline Assessment and Monitoring of Impacts of Dust on the Marine Environment of the ROPME Sea Area

Introduction

Background

Decision CM16/7 of the ROPME Ministerial Council directed that in view of the high significance of the matter, information on the impact of sand and dust storms on the marine environment in the ROPME Sea Area (RSA) be obtained. It mandated that a Concept Paper be prepared to elaborate the issues of the impact of sand and dust storms on the health of the ocean in the RSA, to be followed immediately by a pilot scale project and subsequently by a baseline assessment and long-term monitoring programme. Pursuing these Decisions, a Regional Meeting for the Review of the Concept Paper Elaborating the Issues of Sand and Dust Storms and their impact on Ocean Health in the RSA is conducted during 11-12 October 2015. This forum provides an opportunity to review the general aspects relevant to mineral dust production, transport and deposition in the ocean and consequent biogeochemical and physical impacts in the Region, consider the capacities and resources of the Member States and prioritize the areas of future activities of high significance to RSA. The Meeting will develop a small scale pilot study which will cover part of the region and will allow the identification of gaps and needs that are required to be addressed for a successful implementation of the subsequent larger scale programme. The Meeting will also develop the rationale for the baseline assessment and long-term monitoring "to generate the first synoptic data on sand and dust storms and their impacts on the marine environment in the RSA, collate existing data, assess and mobilise the core expertise of the Member States on the subject and prepare technical capacity grounds for a comprehensive Regional monitoring programme and Regional network of facilities". The present Draft Concept Paper is prepared in this context and is submitted to the First Meeting of the Regional Scientific Group to deliberate upon and finalize.

Need for Baseline Assessment and Long-term Monitoring Programme

Millions of tons of dust, usually from arid and semi-arid areas, are emitted annually to the atmospheric boundary layer (Shi et al., 2012). The large quantities of dust result in severe air pollution, reduced visibility, adverse human health effects and impaired soil fertility. Importantly, mineral dust is a dominant atmospheric aerosol on a global scale and plays an important role in the Earth's climate system. Mineral dust directly affects the climate by reflecting solar radiation and absorbing solar and terrestrial radiation, and indirectly by influencing cloud properties. The radiative effects therefore have important implications for global climate, but form an important uncertainty in climate model predictions (Patey et al., 2015). Dust can indirectly affect the climate by stimulating primary productivity and di-nitrogen fixation in the surface ocean through addition of nutrients such as iron and phosphorus (Zender et al., 2003). For example, variations in iron supply to the Southern Ocean associated with mineral dust are considered to influence atmospheric CO_2 levels on geological timescales through iron fertilisation of primary productivity (Martin, 1991).

The African and Asian low-latitude deserts are the major global sources of dust (Zender et al., 2003). The dust belt includes the Sahara and Sahel, arid and semi-arid regions in Arabia and Central Asia, and the Taklamakan and Gobi deserts in East Asia. The Arabian Plateau and the Tigris-Euphrates Basin in the Middle East are areas of active wind erosion. The most important dust sources in the region include the Tigris-Euphrates River alluvial plain in Iraq and Kuwait, the low-lying flat lands in the east of the Arabian peninsula along the Gulf, and the Ad Dahna and the Rubal Khali deserts (Ginoux et al., 2001). The alluvial plains have the highest frequency of dust storms in the Middle East (Ito, 2013), and the fine sediments from the Tigris and Euphrate rivers allow long distance dust transport. Another dust source area is along the Oman coast, with a low frequency of dust storms (Ito, 2013).

Dust emission estimates for the Middle East range from 221 to 496 Tg y^{-1} (Ginoux et al., 2001; Tanaka and Chiba, 2006; Zender et al., 2003) representing between ca. 12 to 28% of global dust emissions. In recent years dust activities have intensified in the region, and this has been attributed to anthropogenic activities such as damming of the Tigris and Euphrates rivers, retreat of Caspian and Aral Seas, land use changes and land degradation (Al-Awadhi et al., 2014; Ginoux et al., 2012). Enhanced atmospheric dust loadings occur throughout the year in the region, but decrease in winter months. A typical annual cycle shows increases in dust loadings in March and April, a maximum in June and July and a decrease in September (Ginoux et al., 2001).

The RSA receives one of the largest aerosol loadings of any of the world's ocean regions due to its proximity to the Middle Eastern deserts and prevailing wind patterns. The situation in the RSA is comparable to the tropical and subtropical North Atlantic Ocean, which is subjected to large dust inputs from North African deserts (Patey et al., 2015). Dust and anthropogenic aerosols form an important source of nutrients (nitrogen, phosphorus and silicon) and biologically important (e.g. iron, zinc) and toxic (e.g. copper) trace elements to the global surface ocean (Baker et al., 2007; Duce and Tindale, 1991; Jickells et al., 2005), and therefore have an important influence on marine biogeochemical processes and ecosystems. It has been reported that transport of dust from the Sahara and Sahel regions of northern Africa results in increased dissolved Fe concentrations in the North Atlantic Ocean (Measures et al., 2008; Rijkenberg et al., 2008; Rijkenberg et al., 2012; Sarthou et al., 2007; Ussher et al., 2013), which influences di-nitrogen fixation (Mills et al., 2004; Moore et al., 2009; Rijkenberg et al., 2011; Schlosser et al., 2014) and the structure and functioning of microbial communities (Hill et al., 2010). Aerosol inputs into the Northern Red Sea have been reported to have detrimental effects on phytoplankton communities, which has been attributed to enhanced dust-derived copper inputs (Paytan et al., 2009). However, very little is known about aerosol inputs to the RSA and their impacts of ocean chemistry and biology.

Recent studies have shown that anthropogenic emissions have become an important contributor to aerosol deposition to the oceans (Duce et al., 2008; Fomba et al., 2013; Patey et al., 2015). Studies in the tropical North Atlantic Ocean have shown that pollutant aerosols originating from west Africa, Europe and North America become mixed with Saharan and Sahelian mineral dust (Fomba et al., 2013; Patey et al., 2015). The anthropogenic aerosols are derived from agriculture, biomass burning, fossil fuel burning in power plants, domestic heating, automobiles and ships (Ito, 2013; Ito and Shi, 2015; Luo et al., 2008; Mahowald et al., 2009; Myriokefalitakis et al., 2015), and industrial processes including smelting and petrochemical activities. Anthropogenic aerosol particles are typically smaller than mineral dust, and hence can be transported further afield. In addition, a higher proportion of the elements and compounds associated with anthropogenic aerosols dissolve upon deposition in the surface ocean, compared with mineral dust. The following compounds are enriched in anthropogenic aerosols: V, Ni, Cu, Cr, Zn, Cd, Hg, Pb, N, sulphate, organic carbon and black carbon, polyaromatic hydrocarbons (PAHs).

Furthermore, acidic gases emitted from fossil fuel combustion can also interact with mineral dust, leading to dust acidification. This will help to convert insoluble nutrients such as iron and phosphorus into bioavailable forms (Ito, 2013; Ito and Shi, 2015; Myriokefalitakis et al., 2015; Nenes et al., 2011; Shi et al., 2012). The net effect would be an increase in the delivery of bioavailable nutrients and trace elements to the ocean (Ito and Shi, 2015).

The ROPME region has seen pronounced population growth and industrialisation over the last decades (ROPME, 2013), resulting in enhanced environmental pressures on the RSA. Pressures identified by ROPME include oil pollution, radioactive discharges, discharges of household and industrial sewage which provide enhanced metal, nutrient and organic matter loadings, and environmental degradation of coastal zones and overexploitation of living marine resources (ROPME, 2013). The increased frequency of nuisance phytoplankton blooms (red tides) has been considered a major threat to human health and marine ecosystem services in the RSA (ROPME, 2013).

The impacts of mineral dust deposition to the RSA has however not yet been considered, despite reported increased dust activity over recent years (Solmon et al., 2015) and likely a higher contribution to the dust loading of anthropogenic aerosols (both from fossil fuel combustion and anthropogenic dust emission) from increased urbanisation and industrialisation. Anthropogenic aerosols will likely also be transported to the RSA from outside the ROPME region; in particular atmospheric pollution from Pakistan and India will be delivered during the NE monsoon period. The anthropogenic and biomass burning aerosols from the Indian subcontinent can be observed during the NE monsoon period over the North Indian Ocean (December to May), including the Sea of Oman (Myriokefalitakis et al., 2015); the impacts on the health of the ocean are unknown. Furthermore, the RSA is an important shipping region, with annually nearly 50,000 vessels passing through the Strait of Hormuz. Ship´s emissions contain elevated levels of toxic trace elements and compounds (Cr, V, Ni, PAHs, S) which tend to be highly soluble (Ito, 2013; Schroth et al., 2009) and are therefore likely to make a significant but unknown contribution to aerosol inputs in the RSA.

The importance of mineral dust and other aerosols as a source of trace elements, nutrients and other compounds to the ocean has stimulated research into its production, transport, deposition and subsequent dissolution in surface waters. Over the last two decades, satellite measurements have proved indispensable in the evaluation of dust sources and the provision of transport pathways. While they provide unparalleled spatial and temporal coverage of dust transport, it is however hard to extract quantitative information on aerosol concentration, composition and its dissolution in seawater from satellite observations. In-situ aerosol measurements and dust dissolution studies are therefore essential to obtain accurate data (Mahowald et al., 2005). Due to the sporadic nature of dust transport, long-term measurements of aerosols, such as those made at Bermuda, Miami and in the

Canary Islands (Gelado-Caballero et al., 2012; Prospero and Lamb, 2003; Trapp et al., 2010) and Cape Verde (Patey et al., 2015) are essential in order to build up a picture of dust fluxes and composition. Analyses of the total quantity of elements and compounds in aerosols provide information on the total fluxes to the surface ocean. Dissolution experiments with collected aerosols provides data on the fraction of elements and compounds released upon entry of aerosols in seawater (Buck et al., 2006), which is directly relevant to assess biological impacts. Collected aerosols can also be used to assess their effects on surface water microbial communities through short term bottle incubation experiments involving aerosol additions to microbial populations (Hill et al., 2010; Mills et al., 2005; Paytan et al., 2009).

In situ oceanographic observations of the impacts of aerosol deposition on biogeochemical processes and ecosystem functioning and structure in the surface ocean are of great value. A multitude of studies have provided important information about aerosol impacts on surface ocean chemistry, di-nitrogen fixation, heterotrophy and community structure (Achterberg et al., 2013; Guieu et al., 2014; Moore et al., 2009; Schlosser et al., 2014).

The chemical composition and mineralogy of transported dust can be used to identify the original source of the dust (Patey et al., 2015). This will be important for tracing anthropogenic atmospheric pollution sources in view of potential targeted emission reduction legislation. Recent research indicated the importance of dust composition and mineralogy for trace metal solubility (Aguilar-Islas et al., 2010; Sholkovitz et al., 2012), which highlights the need to link aerosol samples to specific sources.

In the light of all these, a number of important questions arise:

- What are the supplies of nutrients, trace elements and organic contaminants to the RSA by total and soluble aerosol deposition?
- What are the contributions of anthropogenic and natural sources to aerosol loadings in the RSA?
- What are the chemical and biological impacts of aerosol inputs to the waters of the RSA?
- How can future decisions be made on reduction of anthropogenic aerosol emissions in the ROPME region to mitigate their impact on RSA ecosystems?

These questions require us to understand and assess the impact of aerosol inputs to the RSA upon agreed baseline parameters.

Definitions and mechanism

Generic definition of Pilot Study, Baseline Assessment and Long-term monitoring programme

The Pilot Study will form a limited study involving up to 3 sampling sites in different parts of the RSA. The Pilot Study will ensure that the overall programme gets underway swiftly, and will also allow identification of gaps and needs for the follow up larger programmes.

The Baseline Assessment will be described in detail in the course of this documentation. However, a generic definition is to be established at the start, in order to delineate the scope of the work and focus the efforts within a framework of feasibility. The generic definition is as follows:

The "Baseline Assessment of Impact of Sand and Dust Storms (BAISDS) in the ROPME Sea Area" is a collective task of assessing Aerosol inputs and their biological impact for a full year in 2017-2018, to be used in references, comparisons and decision making.

The BAISDS-2017 is expected to become a reference status to mineral dust and other aerosols for future times to come.

The Long-term monitoring programme will provide a temporal perspective to regional dust and anthropogenic aerosol concentration changes, and subsequent impacts on the health of the RSA.

Basic approach for the development of Pilot Study and BAISDS-2017, and subsequent Long-term monitoring Programme

In developing the Pilot study and BAISDS-2017, complete harmonization of related initiatives and sharing of responsibilities will occur. The major milestones to be achieved are:

- Meeting of a Scientific Group to finalize the details of Scientific Programme of Pilot Study and BAISDS-2017
- Practical activity of developing the Pilot Study and BAISDS-2017 by way of completing sampling, analyses, interpretation and reporting
- Development of Regional capacity to contribute to and continue the efforts over a long time period by way of strengthening expertise and designating Regional Reference Laboratories

While this is the broader picture, the details will emerge further on in this document.

Objectives and outcomes

The overall aim of this small Pilot scale study is to provide initial data for developing a one year monitoring programme of BAISDS-2017.

Objectives of Pilot Study

- Set-up capacity to undertake aerosol sampling with high volume aerosol collectors
- Collection of aerosols and seawater samples over a 2 months period in the year 2016 at 3 locations in the ROPME Sea Area
- Identification of gaps and needs for larger monitoring programme
- Measurement of total and soluble elements and compounds in the collected aerosol samples
- Measurement of trace elements, nutrients, organic compounds, carbonate chemistry, chlorophyll a and indicators of ecosystem structure in the collected water samples
- Determination of the biological impact of aerosols in selected samples
- Identification of the potential sources and transport pathways of mineral and anthropogenic aerosols in the Region

Objectives of Study of Dust Inputs to RSA during 4 seasonal Cruises in 2016

- Contribute to the 2016 cruise programme through aerosol collection and surface water analysis for assessment of impacts of aerosols on RSA
- Undertake aerosol sampling on cruises using high volume aerosol samplers
- Measurement of total and soluble elements and compounds in the collected aerosol samples
- Determination of the biological impact of aerosols in selected samples
- Identification of the sources and transport pathways of aerosols collected on cruises

Objectives of BAISDS-2017

The overall aim is to provide essential baseline data for developing an international flagship monitoring programme of aerosol impact on the RSA

- Collection of aerosols over a full seasonal cycle in the year 2017 at locations in the ROPME Sea Area
- Measurement of total and soluble elements and compounds in the collected aerosol samples

- Collection of surface water samples over a full seasonal cycle in the year 2017 at locations in the ROPME Sea Area for chemical and biological measurements
- Determination of the biological impact of aerosols over a full seasonal cycle in 2017-2018 in the ROPME Sea Area
- Determination of the impact of aerosols on the water column carbonate system (ocean acidification) over a full seasonal cycle in 2017-2018 in the ROPME Sea Area
- Quantification of the sources and fluxes of mineral and anthropogenic aerosols in the Region
- Determination of the main processes regulating the distribution, transport and the deposition of mineral and anthropogenic aerosols in the RSA
- Chemical transport modelling to integrate the mineral and anthropogenic aerosol data from observations with information on dispersion, transport and biological uptake processes
- Modelling of trace element and nutrient deposition, constrained by remote sensing of total aerosol deposition rates in combination with ground measurements
- Further development of local physical-biogeochemical model with improved aerosol supply fluxes and biological impact quantification
- Use outcomes of the monitoring programme to assess impact of aerosol deposition on health of the RSA and lobby regional governments to reduce anthropogenic atmospheric emissions in the region
- Promotion and strengthening of the capabilities and readiness of the Member States in the domain aerosol mineral dust monitoring and establishment of biological effects
- Archival and integration of relevant atmospheric and oceanographic information to the BAISDS-2017
- Establishment of Regional and international collaborations on the platform of BAISDS-2017 as a networked capacity for future endeavors
- Designation of Regional Reference Laboratories for the continuation of work emanating from the BAISDS-2017
- Establishment of a regular long-term Regional Monitoring Programme including the networking of National Monitoring Programmes on aerosols

Objectives of Long-term monitoring programme

The overall aim is to provide long-term trends on aerosol deposition and the impacts on the health of the RSA

- Quantification of temporal and spatial distribution of deposition fluxes of soluble and total trace elements, atmospheric nutrients and organic pollutants to the ROPME Sea Area from both natural and anthropogenic sources

- Quantification of temporal and spatial impacts of aerosol deposition on water column biogeochemistry, carbonate chemistry (ocean acidification) and ecosystems
- Quantification of anthropogenic sources (dust and fossil fuel combustion aerosol) to the aerosol deposition fluxes
- Refinement of the chemical transport model with the outcomes of the monitoring programme
- Assessment of temporal changes in aerosol deposition and biogeochemical and ecosystem impacts in the RSA
- Development and refinement of RSA biogeochemical model
- Development of effective atmospheric pollutant emission control measures in the region
- Assessment of the effectiveness of atmospheric pollutant emissions in the RSA and benefits to RSA

Expected outcome from Pilot Study

- Small and limited dataset on aerosol deposition and impacts on surface water biogeochemistry and biology for parts of the RSA
- Substantial and high quality dataset from collaborative 2016 cruise campaigns in RSA region
- Gaps and Risks assessment for BAISDS-2017
- Action plan to deal with gaps and risks for BAISDS-2017 implementation

Expected outcome from the BAISDS-2017

- Establishment of a comprehensive geospatial database of previous relevant studies in the Region and experiences gained elsewhere on aerosol impacts, with provision for updating of data from the monitoring stations and networking with other data facilities

- Establishment of a joint information center with dedicated website for collection of required international standards, international guidelines, standard software, data analysis models, standards concerning aerosols as related to marine biogeochemical and ecosystem impacts and decision support tools

- Designation of Regional aerosol dust monitoring facilities and measurement laboratories, and including a cross calibration exercise to guarantee harmonization of the measurements made by each laboratory (capacity building)

- Development of a Regional Monitoring programme for Aeolian mineral dust and its impacts on the ocean through the participation of Member States, including designated stations and standardized operating procedures and equipment

- Establishment/suitable upgrading of aerosol dust analysis stations in the ROPME Sea Area. These stations serve both as a network for Aeolian mineral dust concentration information as well as Aerosol Monitoring System through standardized methodology

- Provision of scientist exchange programme and Regional seminars/ workshops on studies dedicated to marine environment and Aeolian mineral dust and their impacts on ocean health

- Establishment of aerosol dust monitoring and analysis stations, biological impact assessment activities for dust deposition to the ocean, training and collaboration programmes by the Member States

The above outcomes can be targeted in a phased manner on completion of the BAISDS-2017 and presentation of results to the Member States by the Regional Scientific Group.

Expected outcome from Long-term Study

- High quality temporal and spatial data set of Aeolian mineral dust measurements, with their impact on the ocean in the RSA
- Data for policy makers and scientists to establish impacts of Aeolian mineral dust inputs on health of the ocean, including nuisance algal blooms
- Data and evaluation tools for regional policy makers to undertake emission reduction measures with respect to atmospheric pollution
- Strengthened long-term scientific collaborations in the ROPME region

Technical description

Elements of BAISDS-2017

Following are the elements of the technical programme to develop BAISDS-2017, each of which is described in detail below:

1. Geographic coverage
2. Prioritization of monitoring and research issues
3. Target elements and compounds
4. Criteria and selection of suitable sampling sites
5. Sampling Protocol and sample types
6. Sampling Frequency

7. Sampling management
8. Database design and operation
9. Sample analyses issues and Identification of responsible laboratories
10. Inter-calibration and QA/QC procedures
11. Data Management and Reporting
12. Training needs
13. Linkage with other ROPME Activities
14. Integration with other National and Regional Programmes
15. Programme Time-frame

Description of the elements of the technical programme of BAISDS-2017

1. **Geographic coverage**

   BAISDS-2017 is envisaged to cover the ROPME Sea Area. Aerosol sources from both the Middle East and India and Pakistan are expected to be transported to the RSA, and consequently sampling stations will need to be situated at various strategic sites in the ROPME region

2. **Prioritization of monitoring and research issues**

   The basic research issue linked to the BAISDS-2017 is:

   - Background survey

3. **Target elements, compounds, and biological impact assays**

   The priority set of target elements and compounds to be analyzed in collected aerosol samples in BAISDS-2017 are listed below. The elements include essential elements for microbial organisms (e.g. Fe, Co, N, P), but also toxic elements and compounds (Cu, PAHs) and elements that may be involved in nuisance bloom development (N, P). We will also determine the impacts of dust inputs on water column carbonate chemistry, in order to assess ocean acidification effects. On selected samples, we will determine mineralogy using XRD and electron microscope (EM) techniques, in order to contribute to the determination of the source of the aerosol. A comprehensive quantitative source apportionment of airborne particles and soluble trace elements and nutrients therein will be carried out using receptor models. We will undertake atmospheric modelling of trace element and nutrient deposition, constrained by remote sensing of total aerosol deposition rates in combination with ground measurements

   We will undertake water sampling to assess the impact of aerosol inputs on chemistry (including ocean acidification) and biology. We will further develop a local physical-biogeochemical model with improved aerosol supply fluxes and biological impact quantification. Typical anthropogenic gases, such as ozone, NOx and SO_2 are to be determined at selected stations to identify origin of the collected air masses. Multispectral (UV to PIR) atmospheric aerosol optical depth (AOD) will be performed using manual photometers in the frame of the Maritime Aerosol Network (MAN) component of AERONET. Data will be provided to the AEROSOL/MAN data base of aerosol measurements over marine areas (http://aeronet.gsfc.nasa.gov/new_web/maritime_aerosol_network.html).

Elements, compounds, gases and physical measurements	**Matrix**
Na, Mg, Al, K, Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ag, Cd, Sn, Hg, Pb, U, P, OC/EC, PAHs, molecular tracers	Collected aerosols (total fraction)
Na, Mg, Al, K, Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ag, Cd, Sn, Hg, Pb, U, Cl^-, sulphate, ammonium, nitrate, phosphate, silicic acid, sulphate, DOC	Water soluble aerosol fraction
Al, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ag, Cd, Hg, Pb, U, ammonium, nitrate, phosphate, silicic acid, DOC, dissolved inorganic carbon and total alkalinity	Seawater samples
Ozone, VOCs, NOx and SO_2 at selected stations	Gas phase

Aerosol optical depth (AOD, using manual photometer)	Atmosphere
XRD-EM mineral analysis	Particulate aerosol samples

Biological Impact	**Matrix**
Effects of dust deposition on surface water ecosystems (chlorophyll a , photosynthetic efficiency and microbial composition of waters)	Surface seawaters
Dust additions from selected samples to phytoplankton cultures	Seawater phytoplankton culture

4. **Criteria and selection of suitable sampling sites**

Criteria are required to select the optimum sampling sites, for which the following aspects are to be considered:

- Sampling must be cost and effort effective
- Process of selection of sampling sites should consider the wind patterns of the Region and represent locations of importance for the various air masses reaching the RSA, and anthropogenic activities (industry, urban areas, shipping). Air mass trajectory modeling experiments and regional air quality data analysis will be conducted to aid with site selection.
- Existing ROPME Reference sites are to be carefully considered in order to benefit from historical data
- Existing and planned Regional initiatives including surveys should be utilized to undertake Aeolian mineral dust sampling at sea in combination with water column sampling to assess impact of dust deposition. This harmonization will optimize sampling effort and provide important added value to the programme

- Adaptive extension of national efforts should be ensured to cover some sites on the coast as well as in the near-shore environment through national activities as contribution to BAISDS-2017

With these criteria, xx sites as explained below are considered as BAISDS-2017 reference stations.

5. Sampling Protocol and sample types

The standard operating procedure of sampling for aerosols will be to collect total suspended particles (TSP) using high volume aerosol collectors, employing W41 (Whatmann 41) filters and also Quartz (Whatmann QMA) filters. Full digestion will be undertaken on the W41 filters for subsequent elemental analyses by inductively coupled plasma mass spectrometry (ICP-MS). The digestion will involve a mixture of HCl, HNO_3 and HF to obtain complete digestion. A rapid deionized water (e.g. MQ water, Millipore) leach will be undertaken on W41 and QMA filters for subsequent elemental analyses by ICP-MS, and anion analyses by ion chromatography and nutrient analyses by autoanalyser. Dissolved organic carbon analyses will be undertaken using high temperature combustion techniques and PAHs using liquid chromatography. Mineralogical composition will be conducted on selected samples through X-Ray Diffraction (XRD)/EM analyses. A punch of QMA will be used for organic carbon (OC) and elemental carbon (EC) using a carbon analyser. Half of the QMA filters will be extracted with organic solvent for molecular marker analysis by GC-MS.

Water column sampling will be undertaken for nutrients with subsequent analysis using an nutrient autoanalyser. Samples will be collected for organic carbon, organic pollutants, microbial community structure and chlorophyll a analysis. In addition samples will be undertaken for trace elements using specialized trace metal clean techniques. Analysis will be undertaken by ICP-MS following preconcentration and matrix removal. Samples will be collected for carbonate chemistry analysis (dissolved inorganic carbon and total alkalinity). Temperature and salinity will be determined on-site using calibrated probes.

Biological impact assessment of aerosols will be conducted by addition of aerosol sample to phytoplankton cultures during short-term (48 h) incubation experiments, and assessment of changes in biomass (chlorophyll a) and physiological health (Fv/Fm) (Hoffmann et al., 2012).

For BAISDS-2017, we will adopt the aerosol sampling and elemental analysis protocol from the International GEOTRACES programme (Morton et al., 2013). For nutrient and organic analyses we will use standard methods. The Scientific Group will prepare clear standard operating procedures for the full range of activities as part of the sampling and analyses activities.

6. Sampling Frequency

The BAISDS-2017 is an exercise of establishing a reference for the year 2017-2018 over a period of 12 months. As such, a full seasonal cycle will be sampled continuously at the various sampling sites. Filters on the high volume pumps will be changed every 2 days. Filters will be frozen to -20C for subsequent analyses. Water samples will be collected every month.
Daily AOD measurements will be undertaken. At selected sites continuous gas measurements will be undertaken.

7. Sampling management

The sampling process management will be a coordinated operation, requiring cooperation and support of the Member States. The schema is as follows:

- ROPME will be BAISDS-2017 Coordinator and will receive guidance from the Scientific Group.
- BAISDS-2017 Coordinator will establish a sampling schedule, provide necessary technical support and prepare a Sampling Protocol in cooperation with the Regional Scientific Group and GEOMAR to be made available to the members of the sampling management team

8. Sample banking

ROPME shall archive the samples in ROPME-Sample Bank (RSB) under required conditions, pending the dispatch of sub-samples to the central laboratory for analyses.

9. Sample analyses issues and identification of responsible laboratories

One laboratory is designated for the analyses of samples, especially since this is a baseline assessment. For the follow-up monitoring however, further laboratories can be selected and involved by conducting proficiency tests. In case of force majeure, it may be decided to split the samples for analyses amongst different laboratories in the Region.

10. Inter-calibration and QA/QC procedures

This will be carried out as per the relevant Guidelines of GEOMAR

11. Data Management and Reporting

All data generated from the BAISDS-2017, both concerning Aeolian mineral dust and the ancillary environmental information, will be secured under ROPME copyright as they are produced. BAISDS-2017 Coordinator, in consultation with the Scientific Group will validate all the data. The validated data will be managed as per the following schema:

- Data will be archived in ROPME and GEOMAR Data Library
- Data will be organized into technical report with necessary interpretations, with the help of expert consultants
- Technical report will be published by ROPME for circulation
- Data will be hosted on ROPME Integrated Information System (RIIS)

12. Training needs

There is a distinct opportunity for capacity development in the Region for both the participation in BAISDS-2017 and to carry out the follow-up activities, such as a regular monitoring programme. As such, the training needs are for:

- Effective sampling , sample preservation and analyses
    - A training course demonstrating the relevant procedures for sampling and aerosol analyses is planned with the cooperation of GEOMAR for National experts expected to participate in BAISDS-2017. This can be treated as an exercise to 'train the trainers', expecting a cascading effect in the Member States. GEOMAR is to provide the training programme along with the needs and requirements for the training course, so as to help in preparations
- Successful sampling and analyses of samples
    - The designated Regional Reference Laboratory will have the responsibility to train the scientists of the Region periodically to carry out the sampling and analyses of aerosols
- Data management
    - ROPME in cooperation with IOC and GEOMAR and on the platform of RIIS will conduct training programmes on general marine data management as applicable to the Region, from time to time

13. Linkage with other ROPME Activities

Effective linkages/harmonization will be established for BAISDS-2017 with the following ROPME activities, as cited earlier:

- Oceanographic cruises
- Preparation of the State of the Marine Environment Report (SOMER)
- RIIS

14. Integration with other National and Regional Programmes

It is expected that the Member States will offer an opportunity to integrate with their existing and planned national programmes of relevance in order to make BAISDS-2017 cost and effort effective. Voluntary sharing of responsibilities in the aerosol dust sampling programme is one important primary step.

Further, ROPME shall explore the possibility of involving Regional and International programmes of UNEP. In particular, a link to UNEP-ROWA will be important in order to link aeolian mineral dust impacts on rain events on the Indian sub-continent, and the effects of west Asian pollution aerosols on the health of the RSA.

15. Indicative Programme Time-frame

- Finalization of Draft Scientific Programme: January 2016
- Meeting of the Ad-hoc Committee to finalize a detailed Scientific Programme with the identification of sampling team, players and Protocol of sampling – March 2016
- Designation of responsible Laboratories for conducting Aeolian mineral dust and seawater pilot study sampling – April 2016
- 2 weeks Training on sampling and sample preparations: May 2016
- Contribution to 2016 ROPME cruise programme
- Start of sampling for pilot study: Nov 2016 for a period of 2 months
- Completion of sample analyses and reporting for pilot study: July 2017
- Start of BAISDS-2017: Nov 2017 for a 12 months period
- Completion of analyses of samples and reporting for BAISDS-2017: November 2019

Conclusion

BAISDS-2017 is an essential and timely exercise. As structured in the descriptions above, it is feasible to conduct it successfully and establish a reference for future use. Cooperation and establishment of a mechanism for sharing the responsibilities by the Member States is the key to success. Once completed, BAISDS-2017 will stand as a key milestone in the collective efforts of monitoring the Region and rendering our ecosystems protected.

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